## Renewable hydrogen for decarbonising the heat sector: spatio-temporal modelling and optimisation of future $CO_2$-free value chains for Great Britain

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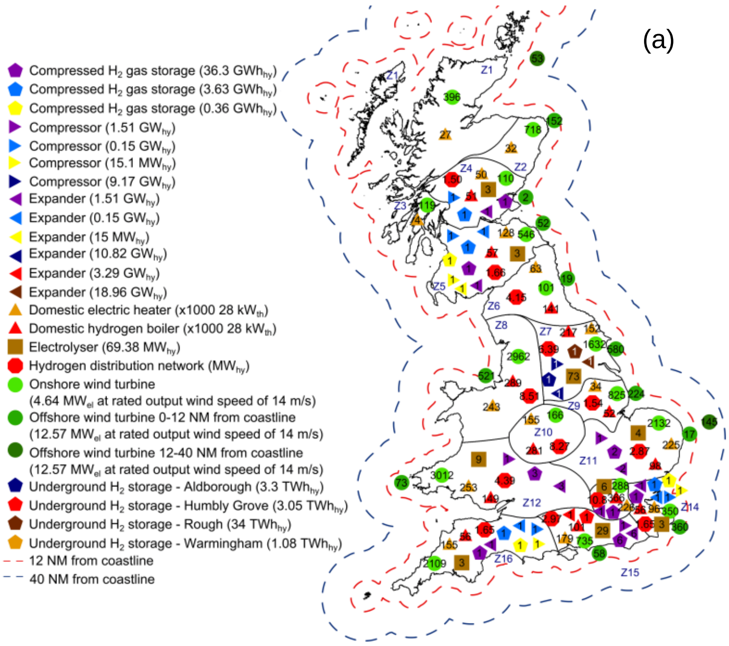
Space and water heating contribute significantly to society's demands for energy. Heat demands, which can be several times those for electricity, are primarily satisfied through natural gas. The cleaner alternative of utilising renewable (or nuclear) electricity along with heat pumps is limited by the capacity of the existing electricity networks and the mismatch of available renewable energy supply to the demands (e.g. solar power is more abundant in the summer when heat demands are lowest and large scale battery storage needed for interseasonal storage may not be available for the foreseeable future). Hydrogen is a promising approach that can overcome these limitations. Low carbon hydrogen can be generated from renewable electricity using electrolysers or from natural gas through SMR coupled with CCS. Both produce clean hydrogen that has a significant advantage when used as a carrier for heat: (1) it can be transported with little loss of energy, which is an advantage over electricity networks, which have losses of about 9% of production, and certainly much lower losses than transporting heat through a district heating network (which are limited in scale due to the cost and inefficiencies of transporting heat long distances); and (2) hydrogen can be stored with little or no loss. Long term direct thermal storage is generally not possible due to the difficulty in insulating the storage devices.

A mixed integer programming model [1] was developed that can optimise different scenarios for generation, storage and transportation of renewable hydrogen to satisfy heat demands. The model considers the spatial distribution of heat demands and the availability of primary resources in order to make a comparison between centralised and distributed generation, as well as to determine the location of hydrogen plants and storage facilities. The temporal representation simultaneously captures the short-term operational issues and long-term planning decisions up to 2050 to examine different pathways from the present time to various potential solutions [2-3]. The model optimises the design and operational decisions to determine the most cost effective/environmentally-friendly transition to the future heat network while also determining what that network should be. Figure 1 illustrates an optimal scenario for a $CO_2$-free renewable hydrogen value chain for heat in Great Britain in 2050.



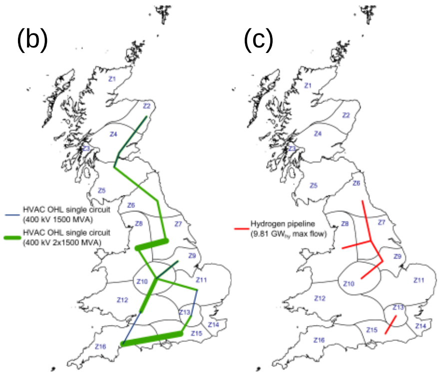



Figure 1. An optimal structure of the renewable value chain for satisfying all of the heat demands in Great Britain in 2050: (a) location, number and type of technologies; (b) new investments in electricity networks (the existing networks are utilised but not shown in the figure); and (c) new investments in hydrogen pipelines.

**References:**

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